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November 1945

United States Department of Agriculture
Agricultural Research Administration
in Cooperation with
The Association of Land-Grant Colleges

SOIL FUMIGATION TESTS IN 1944

Assembled by coordinating committees on soil fumigation investigations of the U. S. Department of Agriculture and of the Association of Land-Grant Colleges, respectively.

Studies of the usefulness of a mixture of dichloropropane and dichloropropylene for the elimination of injurious organisms from the soil were stimulated in 1943 by the publication of certain Hawaiian results with this material. Since many agencies were interested in this field of work, a committee was appointed in the Department of Agriculture to coordinate soil fumigation research. The Bureau of Plant Industry, Soils, and Agricultural Engineering, the Office of Experiment Stations, and the Bureau of Entomology and Plant Quarantine are cooperating in the work. This committee consisted of S. B. Fracker (chairman), H. P. Barss, F. C. Bishopp, B. T. Shaw, and G. Steiner. Subsequently, a similar committee was set up by the Association of Land-Grant Colleges with a membership of E. C. Stakman (chairman), G. H. Godfrey, J. G. Horsfall, and G. F. MacLeod.

A summary of the 1943 results (largely relating to DDT) was duplicated and distributed to collaborating agencies in January 1944. The reports that follow include subsequent tests on a number of the more promising soil fumigants. They are highly condensed in this draft, which is confidential and not available for citation or publication. It is expected that individual investigators will publish their results through the usual channels.

The reports are arranged as in the previous summary:

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(Not for Publication)

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SECTION A: NEMATODES

1. General Considerations (By G. Steiner)

Selection and evaluation of soil fumigants for nematode control. Halogens in various chlorinated and bromated hydrocarbon compounds have again been proven to be the most effective fumigants for nematode control in soils.

Attention may be called to the fact that the active part in fumigants, particularly when of the nature of a gas of higher vapor pressure, when combined with a diluent or liquid carrier, often escapes from the latter. Observed lack of efficacy of fumigants of this type in certain of the experiments here reported is interpreted as being a result of this situation. It should induce manufacturers to find better diluents or carriers. This situation applies particularly to methyl bromide compounds which according to our observations sometimes escape from the diluent or carrier. As a result of the method by which such fumigants are injected or otherwise applied, the diluent or carrier may contain only a part or even a vestige of the active ingredient it is supposed to contain. This results in lowered or no efficacy.

The following table lists the 6 fumigants most frequently referred to in this report:

Trade name	Approximate composition	Manufacturer
D-D	A mixture of dichloropropylene and dichloropropane and a small percentage of other chlorinated compounds.	Shell Chemical Co.
Dowfume G	10% methyl bromide in a mixture of 3 parts ethylene dichloride and 1 part carbon tetrachloride.	Dow Chemical Co.
Dowfume W	15% ethylene dibromide in a "naphtha thinner" (presumably a low-grade gasoline).	Dow Chemical Co.
Larvacide	Chloropicrin.	Innis, Speiden & Co.
Iscobrome	A mixture of methyl bromide, chloropicrin, and xylol.	Innis, Speiden & Co.
None	Carbon disulphide	Various Chemical Cos.

On the basis of the work here reported, chloropicrin, carbon disulphide, D-D, and Dowfume G were again shown to have high nematocidal efficacy and to offer possibilities for use in practical soil fumigation. Iscobrome and mixtures containing ethylene dibromide (e.g. Dowfume W) gave promising results in screening and pilot tests and appear to be worthy of field tests and large scale application tests.

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Soil temperature and efficacy of fumigants. Results here reported strongly suggest that the temperature level at the time of fumigation and the succeeding period of days is highly significant for the efficacy of the fumigant. It appears that temperatures of more than 80°F. are not favorable for successful soil fumigation since they cause a too quick escape of the fumigant. Under such conditions fumigation should be undertaken only if the soil can be tightly enclosed while fumigated or if the area to be treated can be sealed at its surface by various covers (e.g. tar paper, moist sacks, etc.), by sprinkling with water, or by rolling, etc.

Soil moisture and efficacy of fumigants. Experimental results appear to show that soil moisture, unless excessive, does not reduce the efficacy of D-D.

The "near surface survival" of organisms in soil fumigation. Experiments here reported again show that survival and escape of nematodes in fumigation treatments is centered in the surface layers. It further appears that the "killing space" of a fumigant applied at an injection point of e.g. 6 inches depth has the form of an irregular flask or vial, the bottom of which is at some distance below the injection point and the neck is directed toward the surface and surrounds the injection axis.

The relationship of dosage and spacing of injections in soil fumigation. Observations appear to show that there exists a most favorable combination of dosage and spacing of application points. A certain minimum dose of the fumigant applied at injection points of a certain distance gives the highest efficacy. Deviations in dosage or in spacing or in both from this most favorable combination reduce efficacy or increase costs. An increase, e.g. in dosage, above this optimal point does not increase efficacy proportionately. Furthermore, it may damage plants set at or near the injection points through longer persistence of fumes at these points because of the increased dose. The "most favorable combination of dosage and spacing" is however itself a function of various soil factors (e.g. soil type, structure, air space, etc.) and is therefore not a constant but a variable.

Soil fumigation in the grower's time table. From observations based on the experiments here reported the conclusion is drawn that in most regions, particularly the northern and the cooler parts of the U. S., fall treatments should be given preference and spring treatments avoided. Fall treatments not only provide ample time for the fumigant to escape from the soil but usually offer more optimal temperature, moisture, and general weather conditions and avoid interference with the spring planting rush. In the South treatments should be avoided when soil temperatures are at 80°F. and higher.

Nature of physiological action of fumigant on fumigated organism. No information is as yet available as to the exact nature of the toxic action exerted on the nematode organism of any of the fumigants herein reported.

2. Large Scale Cooperative Soil Fumigation Project at Linn, Texas (By J. R. Christie and W. D. McClellan).

During the season of 1944-45, the Bureau of Plant Industry, Soils, and Agricultural Engineering of the U. S. Department of Agriculture in

cooperation with the Texas Agricutural Experiment Station, the Dow Chenical Co., Midland, Michigan, Innis, Speiden & Co., Niagara Falls, N. Y., the Shell Chemical Co., San Francisco, and the Stauffer Chemical Co., N.Y. treated about 50 acreas of land owned by Weatherford Farms and Greenhouses in the Lower Rio Grande Valley at Linn, Texas, with soil fumigants. About one acre, treated in August, was devoted to replicated plots designed to permit critical comparison of the effects of D-D (at 4 rates of application), Dowfume G (at 2 rates of application), Larvacide (chloropicrin), and carbon bisulphide. Slightly less than 30 acres were treated during August with materials provided by the cooperating companies including D-D, Dowfume G, and Larvacide. About 20 acres were treated with materials purchased by the owner of the land, 8 acres during July with Larvacide and 12 acres during December and January with D-D and Dowfume G. The greater part of the treated land (including the replicated plots) was planted with gladiolus, with lesser plantings of lilies, Dutch iris and larkspur and small areas planted with other miscellaneous ornamentals.

The gladiolus at Linn had shown a sharp decline in vigor and productiveness since about 1941. The diseases that appear to have been responsible for this decline and which it was hoped that soil fumigants would control were corn rot caused by Fusarium oxysporum f. gladioli and root knot caused by Heterodera marioni.

From the replicated plots data were taken on the amount of root knot and Fusarium present, number of flowers cut, and the weight and condition of the corms harvested. In no instance was there any significant difference between treatments or between any treatment and the untreated controls.

The large-scale application of Larvacide made during July had little if any effect in reducing root knot. The health and vigor of the crops following treatment (mostly lilies) was not very satisfactory although the cause of poor growth probably included other factors besides root knot. Control of root knot by August applications also was questionable regardless of the fumigant used and, in some instances, definitely poor. Nevertheless the health and vigor of the crops (mostly gladiolus) was very satisfactory. Control of root knot by December and January applications appears to have been fairly good and in some fields treated with D-D, very good. The health and vigor of the crop following treatment (gladiolus) was very satisfactory.

In one field where several different fumigants were applied, Larvacide, Iscobrome No. 2 (a mixture of chloropicrin, methyl bromide, and xylol), and Shell Mixture No. 1 (composition not disclosed) resulted in a marked improvement in the growth of larkspur which, without much doubt, was due to a reduction in the injury caused by Sclerotium rolfsii. This was the only clear-cut evidence indicating control of a fungus.

All the gladiolus grown at Linn during the season of 1944-45 were planted on treated land and total flower cut was about double that of 1943-44. There was also a very substantial increase over 1943-44 in size, quality, and quantity of the corms harvested. In spite of negative results from the replicated plots it seems probable that soil fumigation contributed to this increase in yield though it is impossible to evaluate the extent of this contribution.

3. D-D Fumigation Tests Against Root Knot (By the Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A.).

Work at Klamath Falls, Oregon: Mr. A. E. Gross and Miss Jocelyn Tyler report excellent root-knot control with D-D treatments made November 19, 1943 at a soil temperature of 45°F., moisture of 10.1% and pH 7.0; latin square plot experiments (16 plots); indicator plant, Hubbard squash planted July 19, 1944, roots examined September 6, 1944. Results: Plants from treated plots found free of root galls except two, each from a different plot which appeared to have a single gall; control plots with light to heavy infections.

Mr. A. E. Gross reports perfect control of root knot with D-D treatments applied June 27, 1944 at a soil temperature of 56°F., moisture of 12.1%, arranged as in previous experiment. Results: Plants from treated plots found entirely free of root knot, untreated controls with light to heavy infections.

Work at Puyallup, Washington. W. D. Courtney reports good root-knot control with fall treatments of D-D in two sets of experiments (16 latin squares 6 x 6 ft. each); 10 cc applications 18 inches apart. Indicator crop: Chile squash, spring planted.

Experiment A: Treatments - 9 galls on total of 117 medium sized plants.
Control - 311 galls on total of 92 small plants.

Experiment B: Treatments - 64 galls on 118 medium plants.
Control - 1,073 galls on 121 small plants.

The infected plants were near the plot margins and indicated winter spread rather than incomplete kill.

Spacing and dosage tests at Tifton, Georgia. A. L. Taylor and C. W. McBeth report that at the Coastal Plain Experiment Station applications of 2cc at 14-inch intervals (i.e. 1.7 cc per sq. ft. of surface) or 5 cc at 18-inch intervals (i.e. 2.2 cc per sq. ft.) had given good control of root knot. Larger dosages had shown some toxicity to plants. The question was raised as to what dosages would be the minimum effective amounts at various distances or what combination of dosage and spacing would be best. Injections were made 5 inches deep; spacings tested were 14, 17, and 24 inches; the soil temperature at time of treatment was 26°C. (78.8°F.) and the soil moisture in the plots with 14-inch spacings was 5.0%, in those of 17-inch and 24-inch spacings, 8.3%. Indicator crop: Whippoorwill cowpeas. Results:

a. 14-inch spacings

Control	"	root-knot	count	368
1.5cc	"	"	"	18
3.25cc	"	"	"	5
5.00cc	"	"	"	0

b. 17-inch spacings

Control	root-knot	count		370
2.5cc	"	"	"	14
5.0cc	"	"	"	0
7.5cc	"	"	"	0

c. 24-inch spacings

Control	root-knot	count		254
5.0cc	"	"	"	30
10.0cc	"	"	"	0
15.0cc	"	"	"	0

It appears therefore that under the conditions of the present experiment 2.5cc per injection with a spacing of 17 inches would represent the minimum effective control application of D-D.

Row applications at Tifton, Georgia. Tests by A. L. Taylor and C. W. McBeth at the Coastal Plain Experiment Station, Tifton, Georgia, by applying dosages of 2.5 cc, 4.0 cc, and 5.75 cc of D-D per linear foot of row at a soil temperature of 64°F. and a soil moisture of 5% gave unsatisfactory control of root knot. The chemical was applied by means of an applicator attached to a tractor and the arrangement was so that a raised bed was formed as the chemical was applied. Tobacco was planted and at harvest time the roots were examined for root knot with the following results:

Control	root-knot	count		339
2.5cc application per linear foot	"	"	"	271
4.0cc " " " "	"	"	"	260
5.75cc " " " "	"	"	"	203

There was no toxic effect on plants planted nine days after treatment.

Conclusion: The unsatisfactory root-knot control in these experiments is interpreted to be the result of the raised bed condition which through increase of surface of the treated soil increased the "near surface survival" of root-knot eggs and larvae to a high degree by favoring a quick escape of the fumes of the fumigant. Possibly this escape was also favored by the fact that the top but not the sides of the raised bed were rolled.

Effect of high soil temperature at Tifton, Georgia. A. L. Taylor and C. W. McBeth report that a D-D treatment made at the Coastal Plain Experiment Station, Tifton, Georgia with a soil temperature of 91°F. gave unsatisfactory results as shown in the following table:

Control	root-knot	count		268
2.5cc applications at 14-inch intervals	"	"	"	59
5.0cc " " " "	"	"	"	30
7.5cc " " " "	"	"	"	10

Effect of Different Moisture Levels at Beltsville, Maryland. Greenhouse tests performed by J. R. Christie with an artificially prepared soil and with different moisture levels indicated that there was no appreciable difference in the lateral killing range of a 10cc injection of D-D, whether the soil moisture was 10% or 17.8%; however, when the soil moisture reached 22% a distinct reduction became evident.

The following table shows the effect of soil moisture on the lateral killing range of D-D when used as a soil fumigant to control the root-knot nematode. (Galling on indicator plants : 0, none; 1, trace; 2, light; 3, moderate; 4, severe):

Soil moisture	Galling on indicator plants 4"	8"	12"	16"
10%	0	0	2	4
	0	0	3	4
	0	0	3	3
	0	0	2	4
12.3%	0	0	2	4
	0	0	3	4
	0	0	3	4
	0	0	4	4
14.5%	0	0	3	4
	0	0	3	4
	0	0	3	4
	0	0	3	4
15.3%	0	0	3	4
	0	0	1	2
	0	0	4	4
	0	0	3	4
17%	0	0	3	3
	0	0	2	3
	0	0	4	4
	0	0	3	4
17.9%	0	0	2	4
	0	0	2	4
	0	0	3	4
	0	0	3	4
22%	0	0	4	3
	0	1	3	4
	0	1	4	4
	0	2	4	4
23.5%	0	2	4	4
	0	2	3	4
	0	3	4	4
	0	3	3	4

Therapeutic treatments at Beltsville - tests to cure gardenia plants of nematode infections. Of 12 potted gardenia plants heavily infested with the root-knot nematode, Heterodera marioni, 6 were watered well with a mixture of 1 part of D-D emulsion to 100 parts of water and 6 with a mixture of 1/2 part of D-D emulsion in 100 parts of water. The plants were then not watered for 24 hours. After a week the plants appeared dying, and three weeks after treatment they were examined as to the condition of the roots. Most of the roots had been killed. No living root-knot nematodes were found and the egg masses also appeared killed, even those well embedded in root tissues. Since the crown of all plants appeared still living, all plants were replanted; eventually one of each experimental set died while the rest recovered and exhibited good growth. Six months later the roots of all remaining plants were reexamined as to the presence of root knot; one plant was found free, the others had a light to moderate infection. It is therefore concluded that some eggs obviously escaped the effect of the fumigant.

In other tests, six declining large potted gardenias, heavily infected with a Hoplolaimus species, were submerged in the pots in mixtures of D-D emulsion and water as follows:

2 plants for 10 minutes in a mixture of 1cc of D-D emulsion per gal. of water.
2 plants for 20 minutes in a mixture of 1cc of D-D emulsion per gal. of water.
2 plants for 1 hour in a mixture of 1/4cc of D-D emulsion per gal. of water.

The treatment was not effective; five of the plants died but obviously not because of the treatment but because of the parasite.

Field tests in Maryland. J. H. Machmer reports on a field test with D-D at Glenallen, Md. Original root-knot infestation unevenly distributed; D-D injections 10cc, 18 inches apart, May 30, 1944, soil temperature 78-81°F., moisture 12% to 21%; planted to bush lima beans July 19, readings October 20.

Results: Efficacious control of root-knot on treated plots. Control plants, however, were only lightly infected, although the previous season radish, lettuce, and weeds were heavily, peas only lightly, infected.

Yield: Treated plots - 50 lbs. 4 ozs. beans
Untreated plots - 27 lbs. 4 ozs. beans

4. D-D Emulsion Applied Against the Root-knot Nematode (U. S. D. A.).

Treatment of soil in pots. It was thought desirable to develop a method of treating nematode-infested soil in pots with D-D. Tests conducted by J. H. Machmer appear to show that 0.2cc to 0.6cc of D-D emulsion applied in 100cc of water did not satisfactorily control the infestation in the soil of a six-inch pot; 0.8 to 1.6cc left still a trace of an infestation, while 2.0cc and higher amounts appeared to give eradication. However, all treatments above 0.8cc resulted in retardation of emergence and growth of cucumbers planted 10 days after treatment; the surface of 5 six-inch pots equals 1 sq. ft. and the quantity of soil equals 1/3 cu. ft.

Field test in California. These experiments were designed for the study of wireworm control by M. W. Stone, U. S. Bureau of Entomology and Plant Quarantine at Ventura, California. By chance, the plots located near Barsdale, California, were infested with the root-knot nematode, and G. Thorne was asked to examine them as to the effect of the treatments on this nematode. The plots had been surrounded by low dikes and the solution was applied to them from a large spray tank in which it was mixed. The emulsion was applied in mixtures with water as follows: 1.0cc, 1.25cc, 1.5cc, and 1.75cc per gal. of water; one set of plots received 1 gal. of this mixture per sq. ft., a second set 2 gals. and a third set 3 gals. per sq. ft. Thus dosages of 115 lbs., 144 lbs., 172 lbs., 201 lbs., 230 lbs., 288 lbs., 300 lbs., 345 lbs., 400 lbs., 430 lbs., and 604 lbs., per acre were tested. Treatments were made October 31, 1943 at soil temperatures of from 60°F. to 64°F. at 8" depth. Soil moisture before treatment at 0-8" depth 7.0%, at 9-16" = 15.5%, at 17-24" = 18.1% and at 25-32" = 16.9%; after treatment the moisture content at the same levels was 22.1%, 24.6%, 28.2%, and 25.0% where 3 gals. of the mixture had been applied. Sugar beets and carrots were planted February 16, 1944 and tomatoes April 21, 1944. Treatments of 200 lbs. per acre gave very satisfactory control of the root-knot nematode while those of 400 lbs. and more per acre gave eradication.

Tests in commercial establishment at Beltsville, Maryland. Fall treatment (October) of the badly infested soil (root-knot nematode) of 10 cold frame sashes in a commercial establishment with D-D emulsion, 10cc per sq. ft. mixed with water and applied 1 gal. per sq. ft. gave excellent root-knot control. Seedlings of many types of ornamentals planted in the spring were found free of root galls.

Freeman Weiss reports a reduction of root-knot infection on tomato and delphinium plants through application of 22cc of D-D emulsion in water per sq. ft. of soil. Treatment on December 2, 1943 at 40°F. temperature (cold frames, Plant Industry Station, Beltsville, Md.). This reduction in root-knot infection appears to have caused a significant increase in yield of tomatoes; 56 lbs. from treated soil, 43 lbs. from untreated; 260 tomatoes from treated, 183 from untreated.

5. D-D for the Control of the Sugar-beet Nematode (Heterodera schachtii) [U.S.D.A.].

Tests performed by G. Thorne in Utah gave results as follows: A dosage of 256 lbs. of D-D per acre gave a yield of 27.30 tons of sugar beets as compared with 11.70 tons in the control, or an increase of 133%. The fumigant, applied at 512 lbs. per acre, yielded 20.15 as against 12.35 tons in the control. The extremely high rates of 1,024 lbs. and 2,048 lbs. of D-D per acre gave 14.24 tons and 10.73 tons, respectively. As a result of these high dosages there was an almost complete kill of the nematodes, but there was also injury to the crop. Further investigations will be necessary in order to determine the degree of lasting benefit from these dosages of D-D to evaluate fully their economic significance in production increase.

Experiments with the D-D emulsion by M. W. Stone (BEPQ) near Oxnard, California and read by G. Thorne (for details see above report on: Field test with D-D emulsion in California) whowed that a 600-lb. application

of the D-D emulsion in water resulted in eradication of the sugar-beet nematode while dosages of 345, 403, 431, and 518 lbs. gave satisfactory control.

6. Experiments with D-D Applied in Soil Treatments Against the Root-knot Nematode and a Meadow Nematode (Pratylenchus sp.) Attacking Potatoes (U.S.D.A.).

Work in Western Nevada. G. Thorne of the Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A., reports on various field treatments made in cooperation with the Shell Chemical Co., the University of Nevada Experiment Station, and the Nevada State Department of Agriculture.

(1) Plots at Sparks treated May 9 at a soil temperature of 62°F., a soil moisture of 16%, with 100 lbs., 200 lbs., and 400 lbs. of D-D per acre produced an increased quantity and a better quality of potatoes as compared with the control. However, all the plots appeared to have had a low root-knot infestation and for that reason the present tests are not thought to furnish a proper basis for determination of the nematocidal capacity of D-D. A second field, an old alfalfa stand, treated with 200 lbs. of D-D per acre produced a higher amount of No. 1 potatoes as compared with the control, but root knot was not satisfactorily reduced possibly because of the "soddy" condition of the field at time of treatment.

(2) Plots near Reno, known to be infested with a meadow nematode (Pratylenchus sp.) were treated (Shell machine applicator) with 200 lbs. and 400 lbs. of D-D per acre respectively. The 200 lbs. treatment gave excellent control, the 400 lbs. near eradication. The yield increase, presumably the result of this control, and near eradication of the mentioned meadow nematodes, was asfollows:

Control plot	4,130 lbs.
200 lbs. D-D treatment plot	4,627 lbs., an increase of 12.0%
400 lbs. D-D treatment plot	4,700 lbs., an increase of 13.8%

(3) Plots of a light sandy loam located near Wellington, Smith Valley and having at the time of treatment a temperature of 72°F., and a moisture of 14%, were treated with 200 lbs. and 400 lbs. of D-D. Root-knot control was excellent as shown in the relationship of No. 1, No. 2 and cull potatoes in 25 hills examined for each treatment and the control:

	No. 1	No. 2	Culls
Control	56	11	128
200 lbs. D-D	248	6	17
400 lbs. D-D	240	3	22

As a matter of information a count of so-called free-living nematodes present in these plots was also made and gave the following numbers for soil samples of 1 pound:

Control	6,560
200 lbs. D-D	47
400 lbs. D-D	57

Space of action of fumigants --Utah tests against meadow nematode. Field tests by G. Thorne, Salt Lake City, Utah with D-D and chloropicrin applied at an injection point 8 inches deep in a dosage of 2cc gave a killing space identified by the tabulation below as obviously approaching most closely the volumetric form of a flask or vial, the bottom of which is located at some distance below the injection point while the narrow mouth part reaches the soil surface above it. In these tests larval and adult meadow nematodes (Pratylenchus) and Dorylaimus obscurus found free in the soil served as indicators for nematode kill.

Computation of the Approximate Number of Cubic Inches of Soil in Which Free-living Forms of Pratylenchus and Dorylaimus obscurus were Killed by 2cc Applications of D-D and Chloropicrin

	D-D		Chloropicrin	
Depth	Radius of circle of killing distance from axis of application	Cubic inches	Radius	Cubic Inches
1-2"	1/2"	2	3"	56
3-4"	1	3	5	157
5-6	3	56	8	402
7-8	6	238	8	402
9-10	6	238	7	308
11-12	6	238	6	238
13-14	5(1/2" depth only)	38	6	238
15-16	-	0	5(1/2" only)	39
	Totals	814		1840
	Cu. in. per cc	407		920
	Ratio D-D to Chloropicrin 1:2.26			

7. Soil Fumigants to Control the Golden Nematode of Potatoes (Heterodera rostochiensis Wollenweber) [U.S.D.A.].

Field treatments with various chemicals made in the fall by B. G. Chitwood in the region os Long Island, New York, infested with the golden nematode of potatoes gave the following readings at the end of the 1944 potato season:

Chemical	Application rate lbs./acre	Treatment date	Soil temp. (at 6") when treated °F.	Potato variety grown	Nematode reduction in treated plots %	Potato yields: Total yield in control plots cwt/acre	Yield increase in treated plots cwt/acre	Cost of production: in control plots per/cwt.	Cost of production: in treated plots per/cwt.
D-D	500*	10-8-43	60	Green Mt.	79	36	41	$4.15	$2.85
	863	11-5-43	48	"	98	31	64	4.85	3.65
	863	11-13-43	43	"	87	33	88	4.55	2.40
	1726*	10-8-43	60	"	97	36	28	4.15	6.70
	3452*	10-8-43	60	"	99	36	7	4.15	16.50
Carbon disulphide	1000	11-5-43	48	"	90	31	50	4.85	2.45
	1000	11-13-43	43	"	None proven	33	29	4.55	3.20
	1000	11-28-43	42	Irish Cobbler	" "	89	14	1.70	1.90
Chloropicrin	248	10-8-43	60	Green Mt.	33	36	15	4.15	6.75
	498	10-8-43	60	"	42	36	16	4.15	10.40
	496	11-5-43	48	"	98	31	42	4.85	7.40
	496	11-13-43	43	"	89	33	31	4.55	8.45
Dowfume G	1000	11-5-43	48	"	20	31	41	4.85	4.30
	1000	11-13-43	43	"	None proven	33	33	4.55	4.70
Dowfume P	1000	11-5-43	48	"	87	31	33	4.85	5.00
	1000	11-13-43	43	"	None proven	33	40	4.55	4.11
Dowfume E	1000	11-5-43	48	"	79	31	44	4.85	4.10
	1000	11-13-43	43	"	None proven	33	39	4.55	4.30

* Injury to plants.

It was also shown that heavy dosages of D-D with wide spacing caused injury to plants near the injection point the following spring, while a larger dose per acre, applied in smaller but more closely spaced injection points, gave better nematode control and no injury to the plants.

Over 8000 lbs. of D-D mixture were applied in large-scale cooperative field tests on Long Island, N. Y., in the fall of 1944 to investigate the possibilities of the complete eradication or large-scale control of the golden nematode. The results have not yet been tabulated. These applications were made in a cooperative arrangement between the Division of Control Investigations and Domestic Plant Quarantines, Bureau of Entomology and Plant Quarantine; the Division of Nematology, Bureau of Plant Industry, Soils, and Agricultural Engineering; and the Bureau of Plant Industry, New York State Department of Agriculture and Markets.

8. The Survival of the Potato Rot Nematode in the Surface Layer of Soil (U.S.D.A.

At quite an early stage in studies on fumigation of soil the discovery was made that fumigants tended to leave a residue of living nematodes near the surface where the fumigants obviously escape from the soil with increased speed. It was found that a cloddy surface was a particularly unfavorably situation for successful fumigation since lumps of soil lying on the surface would not even be entered by the fumigant. Raking, rolling, and covering of the soil after fumigation with tar paper, moist sacks, or the creation of a water seal by sprinkling the surface of a fumigated area, and similar procedures were found to more or less counteract a too rapid escape of the fumigant. However, the full extent of the significance of the accelerated escape of fumigants in the surface stratum of soil and its effect on the efficacy of fumigation has never been exactly investigated and it is not infrequently underestimated. An attack on this problem was made in a field study by G. Thorne at Aberdeen, Idaho in pilot fumigation tests against the potato rot nematode, Ditylenchus destructor. The number of surviving nematodes (free-living forms included.) at various depths, based on counts of one-pound samples of soil, are shown in the following table and clearly present the fact of the "near surface survival":

Nematodes Escaping Treatment in One-pound Samples

Depth	D-D 512 lbs. 10cc 18"x18"	D-D 512 lbs. 4.4cc 12"x12"	D-D 200 lbs. 1.7cc 12"x12"	CS2 4.4cc 12"x12"	Clp. 10cc 18"x18"	Clp. 4.4cc 12"x12"	Check
1-2	1,316	692	630	2,643	3,646	1,282	1,764
3-4	156*	3	391	1,208	1,978	614*	3,916
5-6	"	-	29*	776	340*	62*	2,300
7-8	-	-	-	835	300*	213s	2,496
9-10	-	-	-	189	156*	11s	701
11-12	-	-	2s	92	20*	21s	360
13-14	-	-	7s	132	17*	74s	87
15-16	-	-	34*	341	1*	41s	76
17-18	-	-	27*	88	5	7s	17
19-20	-	-	n	n	4	37	8
21-22	-	-	n	n	0	103	12
23-24	-	4*	n	n	0	58	4
	1,471	701	1,112	6,295	6,467	2,523	11,741

0 - No nemas present in sample. n - Not sampled.
s - Saprophagous species only. * - Many dead nemas
These more resistant to chemicals. - - All nemas dead.

9. Comparative Tests of Various Fumigants (U.S.D.A.).

Chloropicrin (Larvacide). A plot at Beltsville, Maryland lightly infested with the root-knot nematode was used for a demonstration of the Innis, Speiden & Co. machine applicator for chloropicrin. The treated area consisted of a central strip bordered on each side by the controls. Dosage 2cc per linear 10 inches or 480 lbs. per acre with water seal; Application May 9; tomato seedlings planted May 27; results as follows:

	Treated area	Untreated area
Total number of tomato plants	66	66
Total weight of ripe fruit (16 pickings from August 8 to October 17)	811 lbs.	478 lbs.
Total weight of green fruit remaining when plants were killed by frost	48 lbs.	23 lbs.
Total number of plants showing root knot at end of test	2	18

The noted increase in yield was probably only partly due to control of the root-knot nematode; control of other nematodes and disease agents (fungi) was possibly also a factor.

Comparative tests with D-D, Larvacide, and Sodium Nitrite. W. B. Courtney, Puyallup, Washington reports the following results: 16 latin square plots, 6x6 ft., 4 replicates and checks, dosage 10cc D-D, 18 inches apart, 2cc Larvacide, 12 inches apart, 1 oz. Sodium nitrite per sq. ft. Treatment: May 5, planted May 24, 1944, temperature 55°F., moisture 19.09%; indicator crop, Chile squash, readings July 13.

Results:	D-D treatments	52 medium-sized plants, 2 root-knot galls.
	Larvacide #	62 large-sized plants, no root-knot galls.
	Sodium nitrite	20 large-sized plants, no root-knot galls.
	Check	32 small plants, 220 root-knot galls.

D-D and Dowfume G. J. R. Christie, J. H. Machmer of the Bureau of Plant Industry, Soils, and Agricultural Engineering and C. A. Weigel of the Bureau of Entomology and Plant Quarantine report on a cooperative test on greenhouse beds at Beltsville, Maryland. treated October 31, 1944 with 4cc injections of D-D or of Dowfume G, 12 inches apart, soil temperature 54°F., soil moisture varying from 10.7% to 14.3%. Planted with squash and cucumbers November 11. Readings February 1, 1945.

Results: D-D gave excellent control of root knot; Dowfume G failed, and it is assumed that the material used had lost most, if not all, of its methyl bromide.

Mixture of D-D and DDT. A pilot test by J. R. Christie proved a mixture of 100 cc of D-D and 258cc of DDT to be no more effective than D-D alone.

Mixture of D-D and Allyl-isothiocyanate. Preliminary tests (performed by J. H. Machmer) with a mixture of 50cc of allyl-isothiocyanate in 450cc of crude D-D were undertaken to determine the efficacy of the mixture which had been furnished by Dr. R. C. Roark of the Bureau of Entomology and Plant Quarantine. Dosages of 5cc, 2.5cc, and 1.25cc were applied each to 1/2 cu. ft. of heavily root-knot-infested soil enclosed in fumigation boxes. All dosages gave eradication. A test in the field (performed by J. R. Christie) with bagged root-knot-nematode inoculum and this mixture (10cc injection) showed it to be no more effective than D-D alone.

Results of screening tests with various chemicals. The results of many screening tests performed by J. R. Christie have been published in the January 1945 number of the Proceedings of the Helminthological Society of Washington, Vol. 12, pp. 14-19. In these tests ethylene dibromide showed an excellent killing range, while that of 1,1,2-trichlorethane was only moderate and that of other compounds and combinations of them was unsatisfactory. These tests showed further that D-D and Dowfume G were superior to chloropicrin in root penetration and therefore kill of nematodes within roots.

2,4 Dichlorophenoxyacetic Acid (2,4D). A pilot test is reported, treating 1 cu. ft. of root-knot-infested soil in a fumigation box by applying 5cc of the chemical in one gal. of water. Katahdin potato plants used as indicator crop exhibited no difference as to degree of infection between treatments and controls, but the plants in the treated soil were late in emerging and of lesser growth.

Catex. This pine tar product, composed of sodium phenolates and sodium resinates is obtained by destructive distillation of pine wood (Southern Pine Chemical Co., Jacksonville, Fla.). A. L. Taylor, Tifton, Georgia., reported wholly negative results with this compound applied in various dosage and spacing tests to determine its efficacy against the root-knot nematode in field trials.

10. Tests by the Pineapple Research Institute, Honolulu, Hawaii.

"The study of soil fumigation was begun as a result of evidence that as pineapple soils became older, the pathological complex increased in severity and it was clear that some contrary action was necessary if production was to be maintained. A second reason was the observation that first ratoons grown on virgin land and in some cases on land treated with chloropicrin were less susceptible to mealybug wilt than were ratoons on old land.

"Weed killers proved unsuitable as well as various organic soil amenders but among a considerable number of chlorinated compounds, one, a mixture of 1,3 dichloropropene and 1,2 dichloropropane, proved to be at least the equal of chloropicrin without any of the disadvantages of that compound.

"D-D mixture, as this compound is designated, can be used effectively without soil cover, is especially effective in nematode-infested soils, and, in an area where Anomala larvae are important factors in a complex which includes Heterodera and Pythium species, the treatment with D-D resulted in especially significant gains.

"The 1,3 dichloropropene fraction of the mixture is evidently the most toxic but there is synergism between that compound and other fractions of the mixture, which suggests that the combination of 1,3 dichloropropene with other chlorinated compounds might be a basis for additional research on soil fumigants.

"Plant growth is seen as the best criterion of the value of a soil fumigant, and it is believed that whatever the effect of the fumigant may be on individual species of the soil complex, the development of good root systems follows effective fumigation." —Walter Carter, Journal of Economic Entomology 38(1):35-44. Feb. 1945.

11. Tests by the California Agricultural Experiment Station.

At the California Experiment Station, D-D mixture was applied six days prior to planting carrots for root-knot nematodes control. The material was applied at the rates of 100, 200, and 300 pounds per acre at 18-inch spacing and 200 pounds at 12-inch spacing. All of the treatments gave satisfactory control of root knot nematode, resulting in an increase in yield of 500 percent. Nematode populations in the soil were

reduced most by applications of 200 pounds per acre at 12-inch spacing. Applications of D-D mixture to nematode-infested soil at the rates of 100, 200, and 400 pounds per acre applied to an 8-inch depth at 18-inch spacing at the Davis Experiment Station resulted in satisfactory control for all treatments.

A large number of experimental plots designed to determine the value of D-D mixture as a soil fumigant for root-knot nematode control were established throughout California by county agricultural agents. Reports indicate that these demonstrations were for the most part satisfactory. Some attempts were also made to control nematodes on living trees but the results up to now are questionable.

In addition, laboratory tests of the toxicity of approximately 30 chemicals to root-knot nematodes in vitro are under way at the California Experiment Station. Other studies under way in California but as yet not reported on are:

1. The effect of D-D treatment upon soil population of root knot nematode and its effect upon subsequent growth of peach seedlings. A total of 112 peach seedlings of three rootstocks have been planted in soil treated with three dosage levels of D-D mixture.

2. Cooperative experiments with sugar beet companies on the effect of D-D mixture upon sugar beet nematodes and the resultant benefits to subsequent crops grown on treated soils.

12. Tests by the Arizona Agricultural Experiment Station

D-D mixture was applied to soils heavily infested with nematodes at three locations in southern Arizona. All of the experimental plots were carefully prepared by cultivation of the soil, and the larger roots from previous plantings were removed by raking. The plots were irrigated to an optimum condition with no fertilizer, either commercial or organic, added after treatment.

D-D mixture was applied to the experimental plots with a recent model "Larvajector". Although this instrument has a tendency to clog, repeated inspections and cleaning of the soil tube point were made so that the D-D mixture is believed to have been regularly and uniformly distributed.

At plot A, 2-1/2 cc. of D-D mixture were injected at 10-inch centers in rows 10 inches apart into sandy loam soil heavily infested with common nematode. Tomato, lettuce, and other plants had previously been entirely killed in this soil. The soil treatment was done on September 22, 1943, and up to October 1944 no root knot had yet appeared on tomatoes and other susceptible plants in this treated soil.

At plot B, situated about 3 miles north of Tucson, a plot of sandy clay loam soil in which winter squash, cantaloupes, cucumbers, string beans and tomatoes had been killed by Heterodera marioni during the

previous season was selected for soil treatment. D-D mixture was injected into this soil at the rate of 2-1/2 cc. applied at a depth of 6 inches and 10 inches apart in rows 10 inches apart. The soil treatments were applied on March 25 and 27, 1944. Up until May 27, 1944, no root rot had been found on watermelon, potato and weed growth in this plot.

In plot C, injections of D-D mixture at the rate of 2-1/2 cc. 10 inches apart in rows 10 inches apart failed to eliminate root knot nematodes in the soil. It was concluded in comparing this plot with other treated plots, that soil temperatures were too low to insure diffusibility of the D-D mixture.

13. Tests at the New York (Cornell) Station

Good control of nematodes in greenhouses was reported with the use of chloropicrin, chloropicrin plus ethylene dichloride, D-D mixture, ethylene dichloride alone, and Dowfume Br 10 (a mixture of ethylene dichloride and carbon tetrachloride). The latter material appeared to be very promising.

14. Tests at the Virginia Station

Excellent control of nematodes was obtained by winter treatment (January) of nematode-infested soils with applications of 125 to 400 pounds of D-D mixture to the acre. At the higher rates of application, injury resulted to celery planted in the treated soil. Applications of 275 to 550 pounds per acre of D-D mixture to soil made in April when soil temperatures of 60 to 64° F. prevailed gave perfect nematode control with no injury to snap beans planted in this treated soil.

15. Tests by the Georgia Station

A strikingly consistent relationship was found between the rates of application of D-D mixture and the incidence of nematodes. The following results were obtained in sandy loam soil by Mr. A. L. Smith at Plains, Georgia:

In a sandy loam plot containing 2.27 percent organic matter, heavily infested with nematodes and previously cropped continuously to cotton, injections of D-D mixture at varying rates were made, and tomatoes were planted in these plots 32 days later to serve as indicator plants for the prevalence of nematode galls. Randomized plots with 5 replications were used in this experiment.

Rate of application (pounds per acre)	% tomato plants showing nematode galls
D-D 192	41.1
D-D 256	21.8
D-D 384	10.3
D-D 512	0
Chloropicrin 535 lbs.	22.2
Untreated	84.7

There was also a striking reduction in the numbers of galls per indicator plant after 40 days from all of the treatments. However, chloropicrin was the only material that showed a significant increase in weight of indicator plants over the check after 40 days. The toxic effects of D-D mixture to the tomatoes growing in treated soil apparently outweighed the benefits from nematode control.

A further experiment was set up at Experiment, Georgia, in sandy loam soil not infested with nematodes. This plot was cropped to sorghum in 1943, and D-D mixture was applied at different rates, after which tomato plants were used as indicator plants. The following results were obtained:

Rate of application (pounds per acre)	Tomato yields (in pounds per plot)
Untreated	12.6
D-D mixture 192	10.8
" " 256	11.5
" " 384	10.6
" " 512	13.9
Chloropicrin 535	12.4

The above differences in yield were not significant although there appears to be some correlation between rates of application of D-D mixture and yields. These results do not appear to support the contention that soil fumigation may result in plant stimulation in the absence of a hazard such as root-knot nematode.

16. Tests at the Hawaii Experiment Station

"D-D mixture and chloropicrin were compared as soil fumigants in an area 25 feet by 160 feet at the Hawaii Agricultural Experiment Station Poamoho Farm, where a heavy population of the root-knot nematode had been built up by prior growth of tomatoes, carrots, and beets.

"Five replications of four treatments were distributed in a randomized block arrangement, with each plot containing a central irrigation furrow.

"Fumigants were injected September 1 and 2, 1943, to a depth of chiefly 5 to 6 inches apart. Soil moisture contents at depths of 2, 6, and 10 inches, respectively, were found to be 27.0, 34.3, and 34.7 percent at that time. Physical condition of the soil was poor, being generally compact with many very firm clods of varied sizes. No soil cover nor water seal was used.

"Morse's Bunching carrot seeds and 20-day Victor tomato seedlings were planted September 10, one row of each per plot, at the sides of the irrigation furrow. Fertilization and care were uniform, agreeing with established practices at Poamoho.

"Data on root-knot infestation of tomato were obtained when alternate plants were dug 26 days after transplanting. Plant weights were obtained the same day. When plants were 11 weeks old, all green fruits were picked and weighed.

"Carrots were harvested when four months old, examined for root knot, graded and weighed.

"Data from tomato and from carrot show all check plots to be heavily infested, no plant being free from galls and the majority being heavily infested. D-D mixture at the rate of 200 pounds per acre reduced the infestation markedly but not as effectively as 400 pounds per acre of either D-D or chloropicrin. These two gave almost identical degrees of nematode control, with very slightly greater percentages of gall-free plants following D-D. Neither, however, fully eliminated moderately to heavily infested plants.

"Fresh weights of 26-day tomato plants were not in close agreement with nematode data, but were greater in all fumigated treatments than in the check, and greatest following 400 pounds of D-D.

"Weights of green tomato fruits were vastly increased -- approximately doubled -- by the fumigants. Yields per plant were greatest after D-D 400, second after D-D 200, and third after chloropicrin. Yields per plot, because of serious bacterial wilt following D-D, were greatest after chloropicrin, second after D-D 200, and third after D-D 400.

"With carrots all fumigation treatments increased total yield, marketable yield, mean weight per carrot and percentage of Grade A, while markedly reducing percentage of culls. The lighter dosage of D-D produced striking gains which were exceeded by both heavier treatments. D-D and chloropicrin, at the 400 pound rate, gave closely similar results with chloropicrin slightly the better. Relative yields of marketable carrots per plot, with the check given a value of 1.0, were: D-D 200, 3.3; D-D 400, 4.2; and chloropicrin 400, 4.6.

"The returns from the experiment station tests for 1944 are as yet incomplete, but the results in general fully confirm the preliminary results of exploratory tests which were conducted in 1943 cooperatively by the Department and several States. They appear to indicate that against the root knot nematode no fumigants so far tested are, in general, more effective than chloropicrin or D-D mixture, when they are properly applied under the right conditions of soil and temperature. The need for much fundamental research on the factors interfering with the effectiveness of soil fumigants was again revealed by the outcome of some of the experiments. A great deal of work will be required to determine the limits of economical and effective action for different types of soil organisms in different types of soils with different moisture and humus contents and with different types of crops and soil management. Troubles with injectors indicated the need for more work on equipment for applying fumigants."

17. Tests in Texas

Treatment of nematode infested soil with D-D mixture at varying rates of application resulted in increases of 25-62 percent in yields of tomatoes planted in these treated areas. Chloropicrin applied at the rate of 500 pounds per acre in the same area resulted in an increase in tomato yields of 60 percent.

18. Tests in Tennessee

Applications of D-D mixture applied to small garden plots apparently eliminated nematodes as the roots of tomato plants grown in these treated areas were free from root-knot nematode infections. In the previous year tomatoes planted in these plots were heavily attacked by root-knot nematode.

19. Tests in South Carolina

In well organized replicated plots good control of root-knot nematode was obtained with applications of D-D mixture and chloropicrin.

Summary of Experiment Station Results on Nematodes in the South

G. H. Godfrey summarized results obtained in the South, as follows, in December, 1944:

"When D-D mixture is applied under most favorable soil conditions (warm soil, slightly moist but not wet, not necessarily confined in any way) it will control the root-knot nematode almost perfectly; will control the meadow nematode; will control at least some fungi (Gladiolus Fusarium, notably); will control certain weeds in the growing condition (notably nut-grass), but not weed seeds.

"When applied in cold wet soils, it is much slower in becoming eliminated from the soil, but is nevertheless effective in killing nematodes and fungi. A very common mistake has been planting too soon after treatment, thus bringing about a retardation of plant growth, resulting in vitiation of the beneficial effect brought about by pest control. Probably 3 weeks is the minimum period one should delay planting, even under best conditions; at least 7 weeks should intervene if the treatment was in cold soil.

"Under ordinary circumstances, chloropicrin requires special measures for gas confinement. When applied under identical conditions with D-D (without special measures such as wet-soil surface), it has generally not given as good nematode control as D-D. It is likely to be eliminated from the soil more quickly than D-D, and therefore planting can be done sooner. A semblance of plant stimulation has resulted after chloropicrin treatment when such stimulation has been lacking following D-D, but this difference has always been traceable to the injurious effects of the D-D, because of too early planting. Chloropicrin is far more efficient than D-D in controlling weeds coming from weed seeds. Chloropicrin is highly efficient as a soil fungicide, and also probably as a bactericide."

SECTION B: PATHOGENIC FUNGI AND BACTERIA

(subsections 1 to 8)

This section covers work conducted in 1944 by members of various Divisions of the Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with State Experiment Stations. The report was assembled by S. P. Doolittle.

1. Verticillium wilt of tomatoes caused by Verticillium albo-atrum. H. L. Blood, Logan, Utah.

Tests were made with D-D mixture, Dowfume Br - 10, Larvacide (chloropicrin), and Carbola (a compound containing phenol).

Plots were approximately 300 square feet and replicated 4 times. Fumigants, except Carbola, were applied with a hand injector at 10-inch intervals and 6 inches deep. Larvacide applied in 2 cc. applications, and D-D and Dowfume in 5 cc. doses. Carbola was applied about the roots of the plants at the rate of 2.3 oz. per plant at time of transplanting. No "water seal" was used because of lack of facilities in the field.

Plants were set 12-15 days after soil treatment. Owing to cold, wet weather the survival was generally poor but there were no significant differences in stand, except with D-D, where 72 percent of the plants were lost. Losses in the check plots and with other treatments varied from 15 to 27 percent. The toxic effect of D-D continued for over 3 weeks and even after replanting the final stand was only 42 percent for D-D as compared to 70-81 percent in other treatments and the check plots. No toxic effects were noted with Larvacide, Dowfume, or Carbola.

No treatment gave anything approaching complete disease control although plants in all treatments showed somewhat less severe disease injury than did the checks. From a commercial crop standpoint, however, the results were not very satisfactory. Soil moisture varied from about 17 to 21 percent in plots of all the treatments. The efficiency of the treatments seemed to decrease as soil moisture increased. Results in general cannot be said to be very encouraging but it is hoped that the work may be repeated under more favorable conditions.

2. Bacterial wilt (Phytomonas solanacearum) of tomatoes. Edward K. Vaughan, Tifton, Ga. (In progress).

This work is now in progress in the greenhouse where infested soil in benches has been treated with D-D mixture, in comparison with treatments with Uramon and with ammonium nitrate. Similar trials will be conducted with field soils during the fall. No results have yet been reported.

3. Watery soft rot, (Sclerotinia spp.) of beans. W. D. Moore, Ft. Lauderdale, Florida (In progress).

Field tests are planned with D-D mixture and chloropicrin to determine their possible value in control of Sclerotinia spp. in various types of soil used for bean production on the lower East Coast of Florida.

4. Soil fumigants for control of Fusarium oxysporum f. lycopersici (tomato wilt organism), F. oxysporum f. gladioli (cause of gladiolus bulb infection), and F. solani f. cucurbitae (cause of wilt of squash). W. B. McClellan, Beltsville, Md.

The fungus to be tested was added to soil in 3 gallon crocks in the greenhouse and allowed to become established. A few days later the fumigants were applied with a pipette at a depth of 5 inches in the center of each crock. Four crocks were used for each treatment and for the checks. Tomato and squash seeds, and gladiolus corms were planted in their respective crocks 17 days after treatment.

Chemicals used and rate of application per acre were:- Carbon bisulfide - 1000 pounds, D-D - 250 pounds, and 500 pounds, methyl bromide - 600 pounds, Dowfume G - 600 pounds, Larvacide e 400 pounds, Innis Speiden No. 2 - 600 pounds, tetrachlorethane - 2000 pounds, 1, 1, 1, trichlorethane - 2000 pounds. Squash seed did not germinate in the soil treated with tetrachlorethane and in an additional set of crocks treated with ethylene dibromide. These were replanted after a 5 weeks interval. Other treatments did not affect seed germination but tomatoes made a slow growth in soil treated with tetrachlorethane.

On January 25, 1945, the tomato plants (4 per crock - total of 16), had shown a considerable amount of wilt with some treatments. Checks in infected but untreated soil showed 4 plants dead; the D-D treatments showed 9 and 10 plants dead respectively; Dowfume - 7 plants; and 1,1,1, trichlorethane - 11 plants; all other treatments showed only from 2 to 4 plants killed.

In the squash tests, (3 plants per crock - total of 12), three of the checks in inoculated soil died and 1 to 2 plants were killed in infected soil treated with D-D, Larvacide, and Innis Speiden No. 1 and 2. With the other treatments, no plants were lost.

Data on gladiolus infection are not yet available.

5. Rotting of chestnuts caused by organisms in the soil. Max B. Hardy Albany, Ga.

D-D mixture in emulsion form was applied to the soil surface around 2 chestnut trees at the rate of 3/4 pint to 625 square feet. Only one application was made and soil was rather dry. No control of rot of the nuts was noted. There has been no evidence of damage to the trees up to this time.

During 1945, several applications of ordinary D-D mixture and the D-D emulsion will be made to the soil about pecan and chestnut trees during the growing season in order to determine whether its use is likely to be harmful to such trees. This information is a necessary preliminary to studies on fungus disease control.

6. Bacterial wilt of tobacco caused by Phyt. solanacearum. T. E. Smith, Creedmoor, N. C.

D-D mixture was applied at the rate of 2, 4, and 8 cc. per square foot in holes made with a shovel at 1 foot intervals and 6 inches deep.

Plants in plots receiving 4 and 8 cc. of D-D showed marked chlorine injury early in the season. However, there was complete wilt control in the plots treated at the 8 cc. rate (920 lbs. per acre). The 4 cc. application gave fair control and it is evident that the material has bactericidal properties.

7. Cotton root rot (Phymatotrichum omnivorum) and fusarium wilt (F. vasinfectum). L. M. Blank, College Station, Texas.

Expt. 1. Planted on Houston black clay soil in Washington Co., Texas. D-D mixture applied in 10 cc. amounts at depth of 6 inches and at 18-inch intervals. Rows 25 feet long. Soil moisture - 37.5%. Mean free air space - 45.37 percent. Cotton root rot known to have occurred in earlier years.

There was no rain for 3 weeks after treatment and odor of D-D persisted until May 30. Seedling emergence was reduced about 30 percent in treated plots but there was little difference in the final thinned stand. Disease counts showed some reduction in the number of affected plants in treated rows but distribution of the fungus was uneven in the land used for the trials. Yields were approximately the same on untreated and treated soil.

Expt. 2. Planted on sandy area in field of dark Wilson-Crockett loam in Washington Co., Texas. Same method of treatment as in Expt. 1. Mean soil moisture - 14.5 percent. Mean free air space - 32.12 percent. Severe damage from fusarium wilt and nematodes in 1943.

Good rainfall after planting. Somewhat reduced emergence in treated soil but final stands were equal. There was slightly less wilt infection on the treated soil but the disease level was so much lower than in 1943 that the differences were without significance. There was partial control of nematode injury by the D-D treatment and roots of plants in treated soil showed many less galls than those from the untreated plots.

Expt. 3. Planted on sandy loam of Luffkin series in Brazos Co., Texas. Same methods of treatment as in Expt. 1. Mean soil moisture - 13.17 percent. Mean, free air space - 47.85 percent.

Seedling emergence was better in treated than in untreated soil. The sandy soil was looser in the bed than that of Expt. 2, or the clay soil of Expt. 1. A longer period elapsed before planting and there were frequent rains.

No disease was observed in any of the plots and no yield records were taken.

8. Verticillium and nematode injury to carrots. G. J. Harrison, Shafter, California

These trials were made in cooperation with the California Experiment Station and the local county agricultural agent. D-D applied at rate of 200 pounds per acre with a field applicator furnished by Shell Development Co. No verticillium infection occurred in either treated or untreated plots but excellent control of nematodes was obtained.

9. Tests on soil microorganisms at Pullman, Wash.

Greenhouse experiments on the value of D-D mixture as a fungicide for soil-borne Fusaria attacking peas were made at the Washington State College of Agriculture, Pullman. D-D mixture was injected into highly organic soil infested with Fusaria known to cause root rot of peas, and peas were planted in this soil 10 days after treatment. Less root and stem rot occurred with peas planted in treated soil than with peas planted in untreated soil but the results were confused due to the apparent toxic effects by D-D residue in the soil.

While these results were not conclusive, D-D mixture appeared to be as effective as Chloropicrin in reducing the incidence of pea root rots caused by Fusarium sp.

It appears that more than 10 days must elapse after treatment with D-D mixture before crops such as peas can be safely planted in treated soil.

10. Tests at Honolulu on Fusarium wilt of tomatoes.

At the Hawaiian Agricultural Experiment Station applications of both chloropicrin and D-D mixture appeared to reduce the incidence of Fusarium wilt of tomatoes. However, applications of D-D mixtures at rates of 200 and especially 400 pounds per acre appeared to increase the severity of bacterial wilt of tomato which was partially controlled by chloropicrin. At the same station soil fumigation with chloropicrin improved the stand of cinchona seedlings but the use of D-D mixture was not as satisfactory for this purpose.

11. Trials in Delaware against Southern Blight.

At the Delaware Experiment Station a plot of land in which 41 percent of the plants were infected in 1943 with Southern blight (Sclerotium rolfsii) was treated with D-D mixture in 1944. On May 3, 1944, this plot was injected with D-D mixture at the rate of 8 ccs. injected 6 inches deep at 18 inch centers, and on May 27 peppers were planted in this treated plot. The peppers were harvested in November and the following results were recorded.

Untreated Soil -- 7.0 percent of peppers infected with Southern blight.
D-D Treated Soil -- 0 percent of peppers infected with Southern blight.

The 1944 season was extremely dry and Southern blight was not a serious problem but the above results indicate that D-D mixture may have some value for the control of Southern blight caused by Sclerotium rolfsii.

12. Tests on Rhizoctonia in Maryland (U.S.D.A.)

J. R. Christie observed excellent control of a species of Rhizoctonia in okra seedlings grown in the greenouse by D-D (5cc), while in the same test Dowfume G (5cc), Ethylene dibromide (5cc), Ethylene dibromide (2-1/2cc) + Trichlorethane (2-1/2cc), Ethylene dibromide (2-1/2cc) + Monochlorobutenes (2-1/2cc), Ethylene dibromide (2-1/2cc) + Dowfume G (2-1/2cc), Ethylene dibromide (1cc) + Trfchlorethane (4cc), Ethylene dibromide (1cc) + Monochlorobutenes (4cc), Ethylene dibromide (1cc) + Dowfume G (4cc) gave no control.

Freeman Weiss reports that tomato roots examined in August 1944 from beds treated with a water solution of 22cc D-D emulsion per sq. ft. on December 2, 1944 (at 40°F. air temperature) were conspicuously freer from Rhizoctonia lesions than those from check beds.

SECTION C: INSECTS

1. White Fringed Beetle

Tests with D-D were made at Gulfport, Miss., in 1943 by the Division of Control Investigations, Bureau of Entomology and Plant Quarantine. At soil temperatures of 70° F. or above, dosages of 12 cc. per sq. ft. covered or 24 cc. per sq. ft. uncovered, produced complete mortality of WFB larvae. Tests in North Carolina in 1944 showed that a dosage of 8.25 cc. per sq. ft. covered at 60° F. was completely effective but that 11 cc. per sq. ft. covered at 52° was only partially effective. At temperatures of 38° and 42° F., 12 cc. per sq. ft. covered was also effective.

D-D mixture was compared with straight methyl bromide and Dowfume E (90% ethylene dichloride, 10% methyl bromide). Methyl bromide definitely ranks first for lowest dosage and effectiveness at lower temperatures. In cases where a less volatile fumigant than methyl bromide is useful, Dowfume E ranks above D-D, having all of its advantages and lacking some of its disadvantages. For this reason, further work with D-D mixture is being discontinued.

D-D is slow in action against white fringed beetle larvae at any temperature, particularly at lower levels unless excess dosages are applied. This is a distinct disadvantage in use under quarantine regulations, where delayed mortality may cause confusion.

2. Pink Bollworm of Cotton

(a) At Presidio, Texas, in January and February 1944 preliminary tests were conducted by L. W. Noble and J. C. Clark with D-D mixture applied as a soil fumigant against pink bollworm larvae hibernating in open cotton bolls. The soil was of a sandy loam type and during the period of the experiments contained a low amount of moisture with temperatures at a depth of four inches ranging from 53° to 75° F. Five methods of application were used on bolls buried four inches deep: (1) Pure liquid injected into the soil after the bolls were buried, with the doses applied 4 inches deep and 18 inches apart; (2) mixed with water (50-50), injected into the soil as above; (3) dilute water mixture sprayed on soil surface after the bolls were buried; (4) dilute water mixture sprayed directly on the bolls immediately before burial; (5) applied in irrigation water.

This material seemed to be slightly more effective when applied in irrigation water than when the pure liquid was injected into the soil. It was more effective in the soil injection method than when sprayed directly on infested bolls before burial. It was least effective when sprayed on the soil surface after the bolls had been buried. Dosages tested ranged from 30.6 to 102 gallons per acre. Although 30.6 gallons per acre caused slightly more than 90 percent larval mortality, occasional larvae were found to survive applications of 76.5 gallons per acre in the soil injection method.

(b) In tests against pink bollworms at Brownsville, Texas, by A. J. Chapman, Bureau of Entomology and Plant Quarantine, late in 1943, infested cotton bolls were installed in one-square yard cages and the bolls were

treated with a D-D water mixture under various conditions so as to determine the effectiveness of different methods of application on pink bollworm mortality. The D-D in each of these tests was mixed with an equal quantity of water and was applied at the rate of 40 cc. per square yard at approximately 51 gallons per acre. The bolls were installed and treated on December 18 and were collected for examination to determine worm mortality on December 22, after an exposure of 90 hours. Three pounds of cotton bolls were installed in each test, but only 1-1/2 pounds of bolls were actually examined to determine the worm mortality. Although there was considerable moisture in the soil at the time the tests were conducted no rains fell during the period of the experiment. The temperature on the soil surface ranged from 37° F. to 79° F. and the temperature 1-1/2 inches below the soil surface ranged from 46° F. to 74° F.

In the first test, bolls were sprinkled with 40 cc. of D-D mixture, then covered with 2 inches of soil. A mortality of 94.1% among 68 larvae resulted.

In the second test bolls were sprinkled with 40 cc. of D-D water mixture and the bolls left on the soil surface. This gave a mortality of 22.6% among 62 larvae.

In test 3 bolls were buried at two depths, 6 inches and 2 inches. Following burial four small holes 6 inches deep and 18 inches apart were made with a broomstick and 10 cc. of D-D water mixture were poured in each hole and the holes immediately covered with soil. Forty-five dead larvae and five live larvae were found in the bolls buried 6 inches, or mortality of 90%, while 31 live larvae and 18 dead larvae were found in the bolls buried 2 inches deep, or a mortality of 36.7%.

(c) In 1944 two series of tests were conducted at Brownsville, Texas, to determine the effectiveness of D-D mixture on the mortality of pink bollworm larvae overwintering in open cotton bolls. In the test installed on January 3, infested bolls were buried in a clay loam soil at two approximate depths 2 inches and 6 inches. The D-D mixture was applied in the bottom of furrows 3 inches deep and 18 inches apart and the furrows immediately covered with soil. Eight days after treatment the bolls were dug up and examined and the number of dead and live larvae were recorded. Although there was considerable moisture in the soil only a trace of rain fell throughout the experiment. The temperature on the soil surface ranged from 34° F. to 83° F. and the temperature 1-1/2 inches below the soil surface ranged from 45° F. to 76° F. The results of the test are recorded below.

Treatment No.	Gallons of undiluted D-D applied per acre	Dilutions used	No. dead larvae	No. live larvae	% control
1	25 +	Mixed 50-50 with water	51	43	50.7
2	51 +	Undiluted	72	15	81.4
3	Check	--	5	64	--

In the second series of tests, installed on February 10, infested cotton bolls were buried in a clay loam soil at two depths 3 inches and 6 inches inside of hibernation cages. As in the previous test the D-D mixture was applied in the bottom of furrows 3 inches deep and 18 inches apart and covered with soil. All the cages were equipped with screen wire covers and traps, and records were made on moth emergence from the different treatments. During the first 10 days following installation, a total of 0.62 inch of rain was recorded. The temperature during this period ranged from 46° F. to 94° F. on the soil surface and from 57° F. to 88° F. 1-1/2 inches below the soil surface. The results of the test are recorded below.

Treatment No.	Approximate number of larvae installed	Gallons of undiluted D-D applied per acre	Dilution used	Moth emergence	% control
1	1554	25.5	Mixed 50-50 with water	158	42.9
2	Do.	51.0	Do.	47	83.0
3	Do.	102.0	Do.	31	88.0
4	Do.	Check	--	277	

As shown, only a slight increase in control was obtained when more than 51 gallons of D-D was applied per acre.

3. White Grubs

Dr. Philip Luginbill and associates at the Lafayette, Ind., laboratory of the Federal Bureau of Entomology and Plant Quarantine used D-D mixture in nine cages previously planted to corn and each infested with 25 white grubs. All grubs were killed in cages receiving injections of 4 oz. or more of pure D-D per sq. yard of soil or from surface treatment at the rate of 60 cc. per sq. yd. At this rate, however, either treatment was injurious to growing corn.

4. Stored-Grain Insects

Dr. R. T. Cotton and Mr. J. C. Frankenfeld at the Manhattan, Kans., laboratory, Bureau of Entomology and Plant Quarantine, made further tests of D-D as a fumigant for stored grain insects. It was highly effective for treatment of wheat for control of stored grain insects at a dosage of approximately 6 pounds per 1,000 bushels. The material, however, even when refined, imparted such an obnoxious odor to fumigated wheat that its use as a grain fumigant was out of the question. Both flour and bread retained a strong garlicky odor that was exceedingly obnoxious. Evidentally there is no possibility of using this mixture as a grain fumigant.

5. Root Aphids and Ants

During the period May 1-13, 1944, several small-scale field tests were conducted by F. F. Bondy, Bureau of Entomology and Plant Quarantine, at Florence, S. C., using a D-D emulsion against two species of root aphids

(Anuraphis maidi-radicis and Trifidaphis phaseoli) and several species of ants including Lasius niger. The emulsion used contained 0.5 percent D-D and 1.0 percent emulsifier (furnished by Norman Allen).

The method of treatment was to pour the emulsion from a glass beaker directly into the mounds formed by the ants around the bases of the cotton plants. From 20 to 50 cc. were poured into each mound.

This emulsion caused no immediate mortality to L. niger even when poured directly onto them, whereas complete mortality resulted to both A. maidi-radicis and T. phaseoli when the emulsion came in contact with them. It apparently failed to kill them unless direct contact with the emulsion was made. The fumes, however, apparently caused the aphids to attempt to leave the roots of the treated plants and they became lost in the surrounding soil. Neither the aphids nor the ants which were on the adjacent hills of cotton, approximately 8 inches away, were affected.

No dead Lasius were found in the mounds treated with this emulsion 24 hours after application but in all cases the mounds were deserted. No live nor dead ants were found in any treated mound. However, mounds not more than 8 inches from the treated mounds were still active after a week.

Two species of ants, Dorymyrmex pyramicus and an undetermined species, were immediately killed by direct contact with this emulsion. It appeared that mortality may have resulted from abdominal penetration of the emulsion in these two species as the abdomen appears softer in these species than in Lasius.

This emulsion killed all of the cotton plants around which it was poured within a week. Three series of 10 plants each were treated and stakes placed by each plant on May 4. These were not molested until May 11, at which time each of the 30 plants was dead. Plants in the next hill, however, were not affected. It appears that if the emulsion comes in direct contact with the roots of seedling cotton, mortality to the plants will result.

Tiger beetle larvae were immediately killed by contact with this emulsion in their burrows. The area in which the hibernation cages are located is heavily infested with these tiger beetle larvae, there being hundreds of burrows within this area. Several of these burrows were treated with the D-D emulsion by filling the burrow completely with it. In each instance the larva immediately came to the surface and in a short time was dead.

6. Green June Beetle Larvae

Plot tests were made at Clarksville, Tenn., by L. B. Scott, Bureau of Entomology and Plant Quarantine. Six replicates were made with 4 cc. of crude D-D mixture per sq. ft. and at twice this dosage. In each case the D-D mixture was mixed with water and applied to a depth of 8 inches in holes 18 inches apart. The materials were applied on April 17 when the soil was wet and cold. The mortality of green June beetle larvae after 4 days was 21 and 23 percent for the 4 cc. and 8 cc. dosages, respectively. In another experiment the 8 cc. dosage gave 42% mortality.

A more extensive series of plot tests on green June beetle larvae was conducted at Florence, S. C., by Norman Allen, Bureau of Entomology and Plant Quarantine. The results were as follows:

Table: Mortality of green June beetle grubs after treatment with crude D-D mixture at Florence, S. C., 1944.

Treatment	Dosage in cc of crude D-D mixture per sq. yd.	No. of larvae recovered	% mortality
Experiment 1 - Applications made March 15, larvae examined March 18 - 2 replicates			
D-D emulsion - 5 percent	400	17	100
D-D emulsion - 2 percent	160	25	100
Undiluted D-D mixture	160	25	100
D-D emulsion - 1 percent	80	20	100
D-D emulsion - 0.5 percent	40	32	97
Undiluted D-D mixture	20	20	85
Experiment 2 - Applications made March 18, larvae examined March 22 - 2 replicates			
D-D emulsion - 0.5 percent	40	68	99
Undiluted D-D mixture	40	59	100
D-D emulsion - 0.25 percent	20	56	96
Undiluted D-D mixture	20	48	92
D-D emulsion - 0.125 percent	10	56	86
Undiluted D-D mixture	10	43	60
D-D emulsion - 0.0625 percent	5	66	21
Undiluted D-D mixture	5	41	24
Experiment 3 - Applications made April 15, larvae examined April 20-22 - 4 replicates			
D-D emulsion - 0.25 percent	20	60	92
Undiluted D-D mixture	20	58	94
D-D emulsion - 0.125 percent	10	55	89
Barium fluosilicate, wheat middlings(4:25)--1/		77	91
Experiment 4 - Applications made on Nov. 6, larvae examined Nov. 11 - 4 replicates			
Undiluted D-D mixture	20	74	79
D-D emulsion - 0.125 percent	20	81	48
Barium fluosilicate, wheat middlings(4:25)--1/		84	62
Experiment 5 - Applications made Dec. 9 larvae examined Dec. 26 - 4 replicates			
Undiluted D-D mixture	20	172	100
Undiluted D-D mixture	30	161	100
D-D emulsion 0.25 percent	20	169	99
Undiluted D-D mixture 2/	20	174	37
D-D emulsion - 0.25 percent 3/	20	188	99

1/ Applied at the rate of 0.18 pound of bait per sq. yd.

2/ Mixed with soil - not placed in holes

3/ Made from emulsible D-D mixture rather than from the crude form.

D-D mixture is very toxic to larvae of the green June beetle when applied in the crude form in holes made by the operator in infested soil or when applied as an emulsion on the soil surface and permitted to soak into the soil.

7. Wireworms

(a) Tests with D-D emulsion applied in irrigation water for wireworm control were made by M. W. Stone, U. S. Bureau of Entomology and Plant Quarantine, near Oxnard, Calif. Applications were made with a spray rig on November 27, 1943, in a field of heavy loam soil having a moisture content ranging from 10 percent in the first 8 inches to 19 percent between 24 and 32 inches deep. Samples of the wireworm populations made on January 13, 1944, showed that 2 or 3 gallons of the dilute emulsion were required per square foot. At the 3-gallon rate using 1.75 cc. of D-D emulsion per gallon of water no living wireworms were recovered. In plots receiving this treatment, however, the odor of D-D mixture was noticeable four months after application. Sugar beets and lettuce planted January 14 in the plots made satisfactory growth. These were 8.8 weed plants per square foot in the plots as compared to 23.6 weed plants per square foot in comparable untreated plots. The affected weeds as identified by Dr. Robbins of the University of California were common groundsel, knotweed, shepherd's purse, nettleleaf goosefoot, sow thistle, malva, and a species of nightshade.

On April 11 an experiment was begun in one-eighth acre plots of medium to heavy loam soil at Oxnard, California, using undiluted crude D-D mixture applied by an injection machine built by the Shell Development Company for the purpose. The soil moisture at the 4-inch depth was 12 percent and the soil temperature was ranging from 61 to 73° F. when the fumigant was applied. The material was applied at a depth of 5 inches at intervals of 18 inches. There were three replicates. Samples of wireworms were taken on the 6th and 7th day after treatment. Fordhook beans were planted in the plots 41 days after treatment. The effect of the D-D mixture on the wireworms and lima beans is summarized in the table below. The results of a similar experiment conducted in sandy loam soil near Ventura, Calif., are summarized in table. (p. 33)

Table: Effect of application of crude D-D mixture to medium to heavy loam soil for wireworm control. Laubacher ranch, Oxnard, Calif., 1944

Gallons of D-D mixture per acre	Control of wireworms a week after treatment	Wireworms in rows of beans planted after treatment	Loss of stand of beans	Yield of green lima beans
	%	No.	%	lbs.
None	--	115	58	274
10	None	105	55	278
20	55	63	53	334
32	70	41	38	332
40	78	28	47	362
58.4	70	11	38	369
Difference required for significance (odds 19:1)	--1/	59	2/	2/

1/ F test following analysis of variance showed that differences in the last 4 treatments were not significant.
2/ Not significant according to F test

Table: Effect of applications of crude D-D mixture to sandy loam soil for wireworm control. G. Chaffee field, Ventura, Calif., 1944.

Gallons of D-D mixture per acre	Control of wireworms a week after treatment	Wireworms in rows of beans planted after treatment	Loss of stand of beans	Yield of green lima beans
	%	No.	%	lbs.
None		155	40	9
17.1		93	40	30
31.5		17	13	42
40.5		10	18	36
Difference required for significance (odds 19:1)		91	1/	1/

1/ Not significant by the F test

At Ventura, Calif., cull beans were planted 4 inches deep in rows 30 inches apart on May 1 to attract wireworms. On May 9 crude D-D mixture was applied by M. W. Stone with a 2-row applicator that placed the material about 1 inch above the bean-bait. Results in 2 replicates 4 days after treatment were as follows:

Gallons of crude D-D mixture	Percent mortality of wireworms
27	100
19	100
15	92
12	100
6	97
None	0

In other tests at Ventura it was found that the lateral diffusion of D-D mixture was much greater in recently spaded soil than in soil that had not been disturbed for 8 months.

(b) In tests by H. P. Lanchester, Bureau of Entomology and Plant Quarantine, at Walla Walla, Wash., D-D mixture was mixed with irrigation water and applied to the surface of plots 3 feet square in which wireworms in small screen cages had been buried at different depths. The mortalities 8 days after 4 gallons of irrigation water were used per square foot are summarized in table. Slightly lower mortalities were obtained when only 2 gallons of irrigation water were used.

Table: Effect of D-D mixture when applied in irrigation water for wireworm control. Walla Walla, Wash.

Gallons of D-D mixture per acre	Mortality after 8 days of wireworms caged at indicated depths: Inches 0 to 3	Inches 3 to 6	Inches 6 to 9	Inches 9 to 12
	%	%	%	%
58	100	100	100	100
29	75	88	100	100
14	75	88	71	65
0	12	47	35	62

In other tests at Walla Walla crude D-D mixture was injected into the soil to a depth of 4 iches in small plots in which caged wireworms had been buried equidistant from the injections. Results are summarized in table.

Table: Effect of D-D mixture on caged wireworms within the soil when injected into the soil to a depth of 4 inches. Walla Walla, Wash.

Gallons of D-D mixture per acre	Distance in inches between injections	Percent mortality June 22	Aug. 9	July 8	Aug. 16
116	12	--	100	--	75
	18	--	100	--	0
	24	--	36	--	0
58	12	100	100	85	0
	18	67	90	10	0
	24	13	0	0	0
29	12	59	100	18	0
	18	40	8	10	0
	24	0	0	20	0
14	12	51	--	40	--
	18	4	--	20	--
	24	0	--	5	--

Summary - Fumigation for Wireworm Control

1. It is evident that much remains to be learned about the uses and limitations of D-D mixture in combating wireworms before we can consider that our research on this material has been completed.

2. Indications are that D-D mixture is effective against wireworms at lower soil temperatures and at higher soil moisture contents than is naphthalene, carbon disulfide, dichloroethyl ether, calcium cyanide, 1, 1-Dichloro-1-nitroethane (Ethide), or chloropicrin. (Information regarding DDT is not sufficient to include this material in the comparisons.)

3. For effective dosages the D-D mixture is more expensive for material and cost of application than naphthalene or calcium cyanide; it involves approximately the same expense as carbon disulfide; and is less expensive than dichloroethyl ether, Ethide, or chloropicrin.

4. For equivalent quantities of materials and under comparable soil conditions the D-D mixture is superior to dichloroethyl ether, Ethide, carbon disulfide, and naphthalene in soil penetration and diffusion and apparently has a longer residual effect in the soil than any other available material except Ethide.

5. With the exception of chloropicrin, none of the other materials is as effective against nematodes as D-D mixture. This is perhaps the outstanding advantage of D-D mixture indicated thus far in the investigations

Table: Percent mortality of Japanese beetle larvae at indicated depths in soil plots at intervals of 5 days and 21 days following treatment with D-D emulsions at various dosages and concentrations per 1000 sq. ft.

Depth in soil	Dosage in pounds of D-D and gallons of water per 1000 sq. ft.						Check-water only
	7.5 lbs. in 200 gal	7.5 lbs. in 100 gal	5.0 lbs. in 200 gal	5.0 lbs. in 100 gal	2.5 lbs. in 200 gal	2.5 lbs. in 100 gal	
Inches	%	%	%	%	%	%	%
			Experiment 1 (May 10)				
			5 days after treatment				
1-2	97.1	95.3	97.9	83.0	92.3	93.5	0.0
6	100.0	100.0	100.0	10.0	49.0	28.0	6.0
9	100.0	94.0	88.0	2.0	22.0	16.0	17.0
12	94.0	35.0	100.0	3.0	3.0	3.0	1.0
16	80.0	74.0	86.0	6.0	4.0	5.0	3.0
			21 days after treatment				
1-2	97.1	97.7	100.0	87.2	95.0	97.8	21.1
6	100.0	100.0	100.0	62.0	95.0	84.0	24.0
9	100.0	100.0	100.0	20.0	75.0	68.0	40.0
12	100.0	93.0	100.0	23.0	37.0	27.0	24.0
16	100.0	90.0	93.0	28.0	47.0	30.0	55.0
			Experiment 2 (June 12)				
			5 days after treatment				
1-2	100.0	100.0	100.0	100.0	100.0	100.0	4.9
6	100.0	100.0	100.0	100.0	100.0	100.0	7.0
9	100.0	100.0	100.0	100.0	100.0	100.0	7.0
12	100.0	99.0	100.0	100.0	94.0	33.0	9.0
16	88.0	55.0	100.0	100.0	90.0	33.0	11.0
			21 days after treatment				
1-2	100.0	100.0	100.0	100.0	100.0	100.0	28.4
6	100.0	100.0	100.0	100.0	100.0	100.0	24.0
9	100.0	100.0	100.0	100.0	100.0	100.0	29.0
12	100.0	100.0	100.0	100.0	100.0	65.0	35.0
16	100.0	100.0	100.0	100.0	100.0	48.0	23.0

Effect on Pupae

Pupae were treated in soil plots using the same schedule of dosages as for the larvae, and in 2 series, one containing a natural infestation and one an artificial infestation.

The data on martality in the first series are shown in the table below:

Table: Percent mortality of Japanese beetle pupae at intervals of 5 days and 21 days following treatment with D-D emulsions at various dosages and concentrations.

Naturally infested soil plots
(percentage)

Days after treatment	Dosage in pounds of D-D and gallons of water per 1000 sq. ft.						Check-water only
	7.5 lbs. in 200 gal	7.5 lbs. in 100 gal	5.0 lbs. in 200 gal	5.0 lbs. in 100 gal	2.5 lbs. in 200 gal	2.5 lbs. in 100 gal	
5	37.7	18.5	0.0	54.6	42.3	11.3	0.0
21	85.8	61.5	49.2	76.9	68.0	71.1	26.2

In the second series 200 mature larvae were scattered on the ground in each of 5 plots, 10 square feet in area. These plots were on the station grounds and in sandy loam. When it had been determined that a majority of the larvae in a control plot had pupated, the plots were treated as described above, except that only the two highest dosages were used. After treatment the plots were covered with screened cages and allowed to remain until any surviving pupae could complete their development and the adults emerge. The mortality percentages, based on adult emergence from the five plots are shown in the following table:

Table: Mortality percentages of Japanese beetle larvae and pupae in soil plots treated with various dosages of D-D emulsions

	Dosage in pounds of D-D and gallons of water per 1000 sq. ft.				Check-water only
	7.5 lbs. in 200 gal	7.5 lbs. in 100 gal.	5.0 lbs. in 200 gals.	5.0 lbs. in 100 gal.	
	%	%	%	%	%
% mortality	98.0	75.5	87.5	62.0	35.0

Fumigation

Japanese beetle grubs, both bare and in 6-inch pots of sandy loam soil, were fumigated with D-D mixture in 5-gallon tin cans which had friction tops. The D-D mixture was placed on filter papers suspended from the lids of the cans. Exposure periods of 2 hours or 48 hours were used for the bare grubs and an exposure period of 2 hours for the grubs in soil the latter period being followed by post-fumigation periods of 6 hours, 24 hours, or 48 hours after which the grubs were removed from the cages and transferred to fresh soil. The tests were run at 50° F.

Table: Mortality of Japanese beetle grubs both bare and in soil two weeks after fumigation for indicated periods with D-D mixture

Dosage ml. per cu. ft.	Bare grub: Exposure period: 2 hrs.	Bare grub: Exposure period: 48 hrs.	Grubs in soil: Exposure 2 hours + post-fumigation: 6 hrs.	Grubs in soil: Exposure 2 hours + post-fumigation: 24 hrs.	Grubs in soil: Exposure 2 hours + post-fumigation: 48 hrs.
1/32	--	24	--	--	--
1/16	20	96	--	--	--
1/8	24	100	--	--	--
1/4	40	100	24	8	16
1/2	24	100	80	76	80
1	100	100	100	100	100
2	--	100	--	--	--
Check	20	28	20	--	20

Conclusions - Japanese Beetle Fumigation

The data indicate that Japanese beetle larvae in sandy loam soil will be killed at levels of 6" and 9" below the surface when D-D mixture in emulsion form is sprinkled on the surface of the soil at the rate of 7-1/2 pounds and in dilutions of 100 gallons and 200 gallons per 1000 square feet. A high percentage of them can be expected to be killed at levels as low as 16" from the surface. A few of the larvae close to the surface may escape, due possibly to rapid evaporation of the insecticide. The same treatments are shown to have killed a high percentage of pupae in both sandy loam and loamy soil.

No injury to grass plots was observed to have been caused by application of D-D mixture at the above rates.

Ethylene dichloride, when similarly applied in experiments reported elsewhere at dosages equal to those of D-D mixture, was more effective in killing Japanese beetle larvae and pupae than D-D mixture.

9. Harvester Ant

Ivan Schiller, Bureau of Entomology and Plant Quarantine, found in one series of experiments conducted at Brownsville, Tex., in October 1943 that harvester ants were all killed in 7 out of 9 nests when 1/2 pint of full-strength D-D mixture was poured into the entrance holes of each nest. In other tests, however, 2 out of 6 nests survived applications of from 1 to 1-1/2 pints per entrance hole.

10. Termites

The Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, found in 1943 that D-D seemed to offer no advantages over several other materials for termite control and has not investigated the mixture further.

SECTION D: EFFECTS ON WEEDS AND GROWING PLANTS

1. Report by M. W. Stone, U. S. Bureau of Entomology and Plant Quarantine, Oxnard, Calif.

D-D mixture is highly toxic to plants and must be applied with care to prevent contact with nearby or adjacent growing crops. It would be dangerous to place it in irrigation ditches or laterals where there is a chance that a break in these ditches or laterals would result in flooding growing crops. Root crops such as carrots and beets have a slight taste of D-D if planted too soon after the material is applied. For safety it appears necessary to apply D-D treatments 5 or 6 weeks before a crop is planted and then to aerate the soil by harrowing or "chiseling" prior to planting. The observance of these precautions might be diffficult in the instance of some crops and in some localities.

2. Weed Control Tests at Pullman, Wash.

D-D mixture was used in a small-scale experiment for possible herbicidal value at the Washington Experiment Station, Pullman. The material was used at the rate of 300 pounds per acre and was injected at intervals of 12 inches at a depth of 6 inches in a field thoroughly infested with bindweed (morning glory). Half of the treated area was covered with craft paper and the remainder was left uncovered. Treatment with D-D mixture in the above manner caused the established bindweed plants to die slowly and 12 days after treatment all of the plants were completely killed. One month after the injections of D-D mixture, the various plots were examined and excavation demonstrated the presence of live morning glory roots at a depth of 14 inches in the covered plots and at a depth of 22 inches in the uncovered plots. At the end of a 2-month period second excavations indicated regrowth from roots at these levels, and approximately 3 months after treatment some plants had reached the soil surface.

It would appear that applications of D-D mixture at the rate of 300 lbs. per acre injected to a depth of 6 inches at 12-inch centers are sufficient to destroy established bindweed plants but will not eradicate this weed from infested areas.

Further experiments are being made at the Pullman station to determine whether or not fall applications of D-D mixture at higher rates and at greater depths will successfully eradicate field bindweed.

The results suggest that D-D mixture has little promise as an eradicant herbicide for annual, broad-leaved weeds.

3. Tests in New Jersey.

In small plots on a greenhouse bench in the Japanese beetle tests no apparent effect was produced on germination when the soil was treated with D-D emulsion at the rate of 7.12 pounds per 1000 sq. ft. 3 days before planting pea, lima bean, bush bean, corn, okra, radish, beet, swiss chard, carrot and lettuce seeds and onion sets. Results observed on a larger

series of plantings in garden plots were inconsistent, due possibly to drought and soil differences, and hence are omitted.

No effect could be observed on grass plots when D-D emulsion was sprinkled on the grass at the rate of 7-1/2 pounds of D-D mixture per 1000 sq. ft.

4. Seed Germination Tests in Maryland.

Greenhouse tests by J. R. Christie; December 1944 and January 1945 to determine the effect of various fumigants upon the germination of lettuce seeds planted immediately after fumigation. The soil (1/2 cubic foot each) of 22 twelve-inch pots (11 different treatments, each in 2 replicates, was injected with the fumigant in the indicated amounts. Readings were made 27 days later. Soil moisture, 11.5% to 16.3%. Soil temperature during first week 62 to 69°F.

Treatment	Germination of lettuce %	Root-knot infection on lettuce
D-D (5cc)	0	---
Dowfume G (5cc)	65	moderate
Ethylene dibromide (5cc)	0	--
Ethylene dibromide (2-1/2cc) and Trichlorethane (2-1/2cc)	0	--
Ethylene dibromide (2-1/2cc) and Monochlorobutenes (2-1/2cc)	0	--
Ethylene dibromide (2-1/2cc) and Dowfume G (2-1/2cc)	0	---
Ethylene dibromide (1cc) and Trichlorethane (4cc)	0	---
Ethylene dibromide (1cc) and Monochlorobutenes (4cc)	0	--
Ethylene dibromide (1cc) and Dowfume G (4cc)	0	---
Steam (soil rested several weeks after steaming)	79	none
Untreated controls	65	severe

5. Weed Control Tests in Maryland.

A soil fumigation treatment with chloropicrin for root-knot-nematode control at Beltsville, Maryland showed on the treated area 642 weeds as compared with 3825 on the untreated plot of the same size; the treatment thus resulted in a reduction of about 83% of the weeds.

6. Weed Control at Tifton, Georgia.

In an experiment at the Coastal Plain Experiment Station at Tifton, Georgia, in row applications of D-D, A. L. Taylor and C. W. McBeth observed herbicidal action as follows:

Control	73 weeds per sq. ft.
2.5 cc applied per linear ft. of row	75 " " " "
4.0 cc " " " " " "	38 " " " "
5.75cc " " " " " "	15 " " " "

SECTION E: PRECAUTIONS TO BE OBSERVED

1. Report from Walla Walla, Washington.

Although if properly handled there does not seem to be serious danger to the operator of being injured by D-D mixture, the Walla Walla staff reported that the effect of D-D on exposed skin was greater than any of the materials they have handled; that it was apt to cause a headache; and that there was a distinct danger of burning if D-D was spilled on the clothing. It was pointed out that it is not necessary to wear a mask when handling chloropicrin or calcium cyanide. The breathing of noticeable concentrations of D-D should be avoided.